Predatory Fish in the Tracy Fish Collection Facility Secondary System: An Analysis of Density, Distribution, Diet, and Recolonization Rates

Investigators

Zachary A. Sutphin
Fisheries Biologist
Fisheries and Wildlife Resources Group
Bureau of Reclamation
Denver, CO. 80225
ZSutphin@usbr.gov

René C. Reyes
Fisheries Biologist
Tracy Fish Collection Facility
Bureau of Reclamation
Byron, CA 94514
RReyes@usbr.gov

Andrew A. Schultz
Fisheries Biologist
Tracy Fish Collection Facility
Bureau of Reclamation
Byron, CA 94514
ASchulz@usbr.gov

Katherine Zehfuss
Fisheries Biologist
Fisheries and Wildlife Resources Group
Bureau of Reclamation
Denver, CO. 80225
kzehfuss@usbr.gov

Summary

The U.S. Bureau of Reclamation's (Reclamation) Tracy Fish Collection Facility (TFCF), located in California's Sacramento-San Joaquin Delta (SSJD), functions to divert and salvage fish preventing them from entering the Delta-Mendota Canal, thereby minimizing fish entrainment and pump induced mortality at Reclamation's downstream Bill Jones Pumping Plant. There are a number of factors (*i.e.*, water velocity, diel period and bypass ratio) that affect fish salvage efficiency at the TFCF (Bowen *et al.* 1998, Sutphin and Bridges 2008). However, predation has long been understood to contribute to significant losses of salvageable fish (Orsi 1967, Liston *et al.* 1994, Fausch 2000), and potentially contributes to unnatural declines (declines that would not occur in the absence of manmade infrastructure) in abundances of native, threatened or endangered species including, but not limited to, delta smelt (*Hypomesus transpacificus*), Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*Oncorhynchus mykiss*), and Sacramento splittail (*Pogonichthys macrolepidotus*). To comply with the Biological Opinion, Reclamation is

required to reduce impacts of predator fish present at the TFCF in order to achieve the highest fish salvage efficiency possible within present day operations and original design limitations. Preliminary data suggest predatory fish accumulate and reside throughout all major components of the facility, including in front of the trash boom and trashrack, the primary channel, primary bypass tubes, and the secondary channel. Nonresident predators are often observed in the holding tank, count bucket, haul bucket, and within the TFCF haul trucks. Predation loss at the TFCF is a major concern and Reclamation biologists have focused significant research efforts in this area, and continue to conduct research to improve predator removal efficiency and personnel safety during such operations. Currently, the primary means by which TFCF employees attempt to improve fish salvage efficiency and minimize fish loss due to predation are predator removals in the facilities secondary channel, which constitutes halting flow of water from the TFCF primary channel, reducing water volume in the secondary channel, flushing each bypass tube with a short duration (~1–2 minutes; min) burst of a high velocity of water, then seining and netting all remaining fish from other components. High densities of predators tend to accumulate in the secondary channel and this is the most safely accessible area prior to fish collection in holding tanks. However, to date there have been no studies completed to assess the impacts of predatory fish in the secondary system or to determine the effectiveness of current predator removal techniques.

Between 2004 and 2006, Reclamation biologists conducted research to determine seasonal abundance, species composition, and effects of piscivores in the TFCF secondary system on salvageable fish. This research included bi-weekly predator removals from six major areas of the secondary system (*e.g.*, bypasses 1, 2, 3, and 4, pre-louver and post-louver) and a subsequent diet study of 30 randomly selected fish of each species collected within three size classes (<100, 101–200, >200) after each bi-weekly predator removal. As a supplement to this research, and to determine the effectiveness of current TFCF predator removal techniques and re-colonization rates, four predator removals were conducted over four consecutive hours on a single occasion (September), followed by four consecutive days of single predator removal efforts. Preliminary data suggest striped bass and white catfish are the dominant predators residing in the secondary year round, and were most commonly collected in bypass one. The mean size of predators collected tended to change with season, with the smallest fish (76–82 mm FL) collected in spring and summer and largest fish (164–225 mm FL) collected in fall and winter. The majority of predators <100 mm didn't have fish in their stomachs, but fish >100 (and fish >200 in particular) generally did. Most of the fish eaten were threadfin shad, and on only two occasions were species of concern (five total Chinook salmon) observed in the diets of sampled predators. Our re-colonization data suggest it takes approximately four predator removal efforts to empty secondary of predators, but predators can potentially re colonize within 3-4 d.

As was outlined in the original study design, August 2006 marked two full years of predator sampling in the secondary system and completion of the majority of data collection. However, there is still a need for additional data on predator re-colonization rates and for all data to be summarized, analyzed, and incorporated into a Tracy Series report.

Problem Statement

Numerous species of predatory fish reside in the secondary channel which may account for a significant loss of salvageable fish and pose a threat to species of special concern. Measuring seasonal abundance, species composition, predatory diet, and effects of piscivores in the TFCF secondary channel is necessary to understanding the overall impact of predatory fish at the TFCF. Determining the effectiveness of current TFCF predator removal operations will provide an understanding of the importance of continuing efforts to develop new predator removal techniques at the TFCF.

Goals and Hypotheses

Goals:

1. Determine if season (month and temperature) affects the total abundance of predatory fish, as a function of size-class, in the TFCF secondary channel.

2. Determine if density of fish moving through the TFCF affects the total abundance of predatory fish, as a function of size class, in the TFCF secondary channel.

3. Determine if water velocity affects the abundance of predatory fish, as a function of size class, in the TFCF secondary channel.

4. Determine if season, water temperature, secondary channel water velocity or density of fish moving through the TFCF affect the distribution, as a function of bypass tube and major components, of predatory fish in the TFCF secondary system.

5. Quantify prey selection of predatory fish species in the secondary channel at the TFCF.

6. Determine if differences in size of predatory fishes (within and across species) affects prey selection.

7. Use bioenergetics modeling to estimate the seasonal effect of predatory fish in the secondary on overall fish salvage.

8. Estimate the seasonal re-colonization rate of predatory fish in secondary facility after predator removal.

Hypotheses:

1. Month has no affect on the abundance of predatory fish in the secondary channel.

2. Density of fish salvaged at the TFCF has no affect on the abundance of predatory fish in the secondary channel.

3. Water velocity in the secondary channel has no affect on the abundance of predatory fish in the secondary channel.

4. Season, secondary channel water velocity, and density of fish salvaged at the TFCF have no affect on the abundance of predatory fish in the secondary channel.

5. There is no significant difference in consumption of prey fishes by predatory fish species compared to availability of prey fishes in the secondary channel at the TFCF.

6. There is no significant difference in consumption of prey fishes with regard to size of predatory fishes compared to availability of prey fishes in the secondary channel at TFCF.

Materials and Methods

Predator Abundance — Bi-weekly predator removals in the secondary system were conducted from June 2004 to July 2006. Date, time of day, tide level, water temperature and length in time of sampling effort were recorded (at least 30 seconds of "flushing" each bypass). Total weights (kg) were obtained for each of the six sampling sites: Pre-Louver, Post Louver, Bypass 1, Bypass 2, Bypass 3, and Bypass 4. All fish were measured (mm FL).

Predator Diet — For our diet analysis, the first 30 of each species (randomly selected) within three size classes (<100, 101-200, >200) were euthanized (50 mg/L of MS222; Argent Chemical Laboratories, Inc.). Fork length (mm), weight (g) and maximum girth (mm) were recorded. Diet contents were removed from all euthanized fish: (1) consumed fish were identified down to species and standard length recorded and (2) invertebrates were identified to genus and no measurements were taken (only presence and absence). Partially digested fish species were identified by J. Wang or R. Reyes to nearest genus possible.

Bioenergetics — Water temperature, estimated prey energy density, diet proportions (derived from our predator diet data), and weight at collection will be incorporated into a bioenergetics model (Fish Bioenergetics 3.0, University of Wisconsin) to estimate consumption rates of predatory fish in the TFCF secondary.

Predator Re-colonization — To determine the efficiency of the current method for removing predators and to quantify re-colonization rates of predators in the secondary system, predator removals were conducted on four consecutive hours (8, 9, 10 and 11am) in an attempt to remove all predators. The following 3 d after this effort, we conducted standard predator removals (no diet analysis).

Secondary predator abundance and diet analysis data collection was completed in August of 2006. However, our initial sampling effort failed to include enough seasonally dependent information on the re-colonization rates of predatory fish after removal from the secondary. In FY 2011 we propose to conduct four additional weeks of predator removal efforts as described in the *Predator Re-colonization* section. To encompass the entire seasonal range at the TFCF we will collect additional information on the re-colonization rates of predators in December, March, June, and September of 2011.

Data Analyses

Predator Abundance — Statistical analyses will be performed using Sigmastat 3.0 (Jandel Scientific, San Rafael, California) software package. Effects of season, water velocity, and fish abundance (estimated fish salvage) on total secondary predator abundance will be modeled using regression. Differences between predator abundance as a function sample location, season, size and velocity will be tested using a four-way Analysis of Variance (ANOVA; Zar 1984, Steel *et al*. 1997). The Tukey's test will be used for all pair-wise multiple comparisons for parametric data. The Shapiro-Wilk's test for normality and the Levene's test for homogeneity of variances will be used to determine ANOVA assumptions. Data that do not meet the ANOVA assumptions and is unable to be power or log transformed will be compared using non-parametric alternatives (Zar 1984, Steel et al. 1997). Differences will be considered significant at $P<0.05$.

Predator Bioenergetics — Fish Bioenergetics 3.0 (University of Wisconsin) will be used to estimate food consumption of predatory fish in the secondary TFCF channel. These data, paired with our predator diet data, will be used to estimate the seasonal effects of TFCF predators on fish salvage.

Predator Re-colonization — We plan on collecting four data points, over four seasons, on re-colonization rates of predators after predator removal in the secondary TFCF channel. Therefore, re-colonization rates will be summarized, but no statistical analyses will be performed.

Predator Diet — Prey selectivity will be measured using Jacob's modified electivity index, which is a modification of Ivlev's electivity index (Jacobs 1974),

$$D = (r - p)\,(r + p - 2rp)^{-1}$$

where D is the index of electivity, *r* is the proportion of the resource used by fish, and *p* is the proportion available in the environment. The index produces values between -1 and +1, where -1 indicates total avoidance and +1 total preference. The modified electivity index is independent of the relative abundance of prey items in the environment, and is used when relative abundance of prey items differs. The value obtained is very similar to Ivlev's index, but it is unaffected by changes of food composition in the environment (Jacobs 1974).

The percent empty stomachs and mean stomach fullness (Terry 1977) depending on time of year will be calculated using regression analysis. Mean stomach fullness among the secondary sampling sites will not be compared because stomachs were randomly selected and pooled from the different sites. As fish grow larger, they often select larger prey (Jobling 1994, Gill 2003). A relationship between length of predator and weight of ingested prey will be compared for the three predator size ranges. Finally, weight-length relationships for each predatory species will be plotted and dominant predator (*i.e.,* striped bass and channel catfish) weight-length relations will be compared with other studies conducted recently on the same species (*e.g.*, Bulak *et al.* 1995, Tucker *et al.* 1998).

Coordination and Collaboration

Experimental design and research updates will be provided at requested TTAT and/or CVFFRT meetings. However, primary coordination and collaboration will be between TFCF staff and biologists, the Fisheries and Wildlife Resources Group, SAIC government contractors, and the interagency TTAT.

Endangered Species Concerns

No ESA listed species will be encountered throughout the remainder of this proposed research.

Dissemination of Results (Deliverables and Outcomes)

Research updates will be provided and/or presented at regularly scheduled Tracy Technical Advisory Team (TTAT) and Central Valley Fish Facilities Review Team (CVFFRT) meetings. The primary deliverables will be a Tracy Volume Series, as well as a publication in a peer-reviewed scientific journal. In addition, posters and/or oral presentations will also be given at appropriate scientific meetings (*e.g.*, CALFED Science Conference, IEP workshops).

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